INTEGRATED FIBER ATTACH PAD FOR OPTICAL PACKAGE

TECHNICAL FIELD

[0001] The present invention relates generally to fiber-coupled optical components and, more particularly, to an integrated fiber attach pad for optical components and packages.

BACKGROUND OF THE INVENTION

[0002] The importance of achieving accurate mutual alignment of individual components in any optical system is well known. The miniature dimensions of components used in modern optical communication systems render such alignment difficult both to achieve and to maintain. For example, one problem in the construction of laser transmitters is that of efficiently coupling the optical output signal from a laser diode into an optical fiber. To obtain efficient coupling, the laser is desirably precisely aligned with the acceptance area of the optical fiber. When such alignment is achieved, the laser is then fixed in place, ideally by a method that ensures alignment is sustained throughout the device lifetime.

[0003] Typically, fiber-coupled diode lasers are packaged in gold plated metal packages and the fiber is held in alignment with the laser using either epoxy, laser weld, or solder attachment techniques. Epoxy attachment is low cost but is not reliable over a long period of time due to outgassing and alignment shifts arising from aging and temperature cycling. Laser weld techniques are reliable but require costly ferrulization of the fiber and specially designed mounts or clips to allow weld attachment of the ferrulized fiber. Solder attachment techniques, on the other hand, are reliable and low cost, and have become prevalent in the art.

[0004] The mounting point at which the fiber is soldered desirably has specific material properties in order to work effectively. An acceptable material for the mounting point desirably has a low thermal conductivity (e.g. less than 50W/m-K) and a thermal expansion coefficient (TEC) that maintains fiber alignment while the package is heated. The exact thermal expansion property desired may depend on the material to which the

laser is mounted, the respective thickness of the fiber mount and laser submount, and/or the temperature profiles expected during operation. The fiber mount material also may be soldered or be able to be plated with a solderable material. During the soldering process, the fiber mount may experience significant stress resulting from differential expansion due to temperature gradients and materials differences. Therefore, the fiber mount desirably has a high tensile strength (e.g. greater than 25kpsi) to avoid fracturing.

[0005] Currently, fiber-coupled laser packages include separate mount components for the fiber and the laser and primarily have a snout feedthrough for the fiber to enter the package body. This feedthrough requires the fiber to be threaded through at some point in the assembly process, which may cause manufacturing complications, as feeding a fiber through a side tube on a package may be difficult to implement with standard automated manufacturing equipment. Since the associated feedthrough step includes horizontal threading of the optical fiber, it is difficult to automate and causes yield issues associated with fiber damage.

[0006] During manufacture of fiber-coupled laser packages, it is also desirable to monitor the alignment of the optical fiber with the laser using cameras and machine vision. Desirable views may include an overhead view of the process as well as side views of the process. In many of the currently used packages, however, it is difficult to obtain a side view of the fiber-laser alignment area, which presents complications to automation monitoring.

[0007] In addition to the problem of the snout feedthrough and the lack of a desirable side view of the fiber-laser alignment area, current packages employ a separate mount for the fiber and may further employ a separate mount for the laser. This may present complications in desirably matching the TEC of each mount to a base material, and further introduces extraneous manufacturing parts and steps in obtaining and securing each mount to the base material.

SUMMARY OF THE INVENTION

[0008] The present invention is embodied in a fiber-coupled optical component housing comprising a substrate having a substantially planar fiber mount region and an optical component mount region adjacent to the substantially planar fiber mount region.

[0009] The optical component housing may include a metallic mount pad formed over the substantially planar fiber mount region and configured to bond to a metal solder preform, and may further include a metallized optical fiber coupled to the metallic mount pad by the metal solder preform.

[0010] In an alternate embodiment, the optical component housing may include a fiber mount pad formed over the substantially planar fiber mount region and configured to bond to a glass solder preform, and may further include a bare optical fiber coupled to the fiber mount pad by the glass solder preform.

[0011] In further embodiments of the present invention, an optical component may be placed or formed within the area defined by the optical component mount region to couple, optically, the optical component and the optical fiber.

[0012] It is to be understood that both the foregoing general description and the following detailed description are exemplary, but are not restrictive, of the invention.

BRIEF DESCRIPTION OF THE DRAWING

[0013] The invention is best understood from the following detailed description when read in connection with the accompanying drawing. It is emphasized that, according to common practice, the various features of the drawing are not to scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. Included in the drawing are the following figures:

[0014] Fig. 1A is a perspective view of a fiber-coupled optical component package showing the snout feedthrough for an optical fiber and the optical fiber soldered to a separate mount component within the package, according to the prior art;

[0015] Fig. 1B is an enlarged view of a portion of the package shown in Fig. 1A, according to the prior art;

[0016] Fig. 2 is an overhead plan drawing of the housing mounted on the base with leads attached, according to the present invention;

[0017] Fig. 3A is a side plan drawing of the housing mounted on the base with leads attached, according to the present invention;

[0018] Fig. 3B is an overhead plan drawing of the top layer of the optical component housing, according to the present invention;

[0019] Fig. 3C is an overhead plan drawing of the bottom layer of the optical component housing, according to the present invention;

[0020] Fig. 4 is an overhead plan drawing of the housing mounted on the base with leads attached and an optical component in place and wirebonded to electrical contacts, according to the present invention;

[0021] Fig. 5 is an exploded perspective drawing of a package, according to the present invention;

[0022] Fig. 6 is a perspective plan drawing of a package with attached components, package lid in place and with fiber sealant in place, according to the present invention;

[0023] Fig. 7 is a flow chart outlining an exemplary manufacturing procedure according to the present invention;

[0024] Fig. 8 is a plan drawing of an alternate embodiment of the present invention showing an optical component and fiber mount formed on the same substrate;

[0025] Fig. 9 is a flow chart outlining an exemplary manufacturing procedure according to the present invention as embodied in figure 8;

[0026] Fig. 10A is a perspective plan drawing of a package according to the present invention;

[0027] Fig. 10B is a cross-sectional side plan drawing along the cut line 10B-10B of the package in Fig. 10A, according to the present invention;

[0028] Fig. 11A is a perspective plan drawing of another package according to the present invention; and

[0029] Fig 11B is a cross-sectional side plan drawing along the cut line 11B-11B of the package in Fig. 11A, according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0030] Referring now to the drawing, in which like reference numbers refer to like elements throughout the various figures that comprise the drawing, Figure 1A shows a package 100 according to the prior art and Figure 1B is a close up of a portion of package 100.

[0031] The prior art package 100 includes optical fiber 114 inserted through snout feedthrough 101 and attached to fiber mount 102 with solder 103. Optical fiber 114 is also optically coupled to optical component 111 (e.g. semiconductor laser). It can be seen that optical fiber 114 is mounted on a separate fiber mount 102 than optical component 111 and that there may be the lack of an available side view on the area where fiber 114 is to be aligned and coupled to optical component 111. Further, the insertion of fiber 114 through snout feedthrough 101 may require a non-vertical manufacturing process, which may cause complications in the manufacturing process resulting in yield issues.

[0032] Figure 2 shows an exemplary embodiment of the present invention as a basic package with high thermal conductivity (e.g. 130 W/m-K) base 200 with fiber-coupled optical component housing 210 mounted on base 200. Housing 210 defines an optical component mount 211 to which an optical component such as a laser within a standard submount package or an unpackaged semiconductor laser (not shown in figure 2) may be coupled. Housing 210 may further include fiber-mountable pad 313 to which an

optical fiber (not shown in figure 2) may be coupled, and electrical contacts 303 to which electric leads 203 may be coupled to provide operational power to the package. Housing 210 may further include a seal ring 314 to which a package lid (not shown in figure 2) may be coupled.

[0033] Figure 3A shows a side plan drawing of an exemplary embodiment of the present invention, and shows housing 210 as comprising housing bottom layer 300 and housing top layer 310 with electrical leads 203 coupled to housing bottom layer 300.

[0034] Figure 3B shows an exemplary embodiment of top layer 310, which may have a thermal conductivity less than that of base 200 (e.g. 20 W/m-K). Top layer 310 includes a top layer substrate 315 upon which seal ring 314, fiber-mountable pad 313, and top layer aperture 311 may be formed.

[0035] In one embodiment of the invention, seal ring 314 and fiber-mountable pad 313 may be formed from a refractory material (e.g. tungsten) to be plated with nickel and then gold, wherein an optional thin strip of metallization 316 may be desirably formed to electrically couple seal ring 314 and fiber-mountable pad 313 so that they may all be electroplated in a single step.

[0036] Figure 3C shows an exemplary embodiment of bottom layer 300, which may also have a thermal conductivity less than that of base 200 (e.g. 20 W/m-K). Bottom layer 300 includes a bottom layer substrate 305 upon which electrical contacts 303 and bottom layer aperture 301 may be formed. Electrical contacts 303 may be desirably formed from a refractory material (e.g. tungsten) to be plated with nickel and then gold.

[0037] In one embodiment of the invention, one or more base-connecting vias 306 may be formed to couple one or more of seal ring 314, fiber-mountable pad 313, and metallization 316 on top layer 310 to base 200 so the entire package may be electroplated with minimal connections (e.g. one connection to base 200 and another to electrical leads 203). Base-connecting vias 306 may also provide a negligible thermal path to base 200 to dissipate heat during device operation. In the exemplary embodiment illustrated by figure 3C, bottom layer 300 is shown to contain two base-connecting vias 306. It is understood,

however, that other embodiments of the present invention may contain any number of vias as desired.

[0038] In an exemplary embodiment, the high thermal conductivity base 200 may be desirably formed from copper-tungsten (Cu-W) and substrates 305 and 315 from aluminum oxide (alumina), due to the desirable thermal expansion coefficient (TEC) compatibility of these materials. Further, electrical leads 203 may be formed from a nickel-cobalt-iron alloy (e.g. Kovar, ASTM alloy F15).

[0039] Additionally, housing top layer 310 and housing bottom layer 300 may be desirably coupled to form housing 210 through a high temperature cofired ceramic (HTCC) process; and housing 210 and base 200 may be desirably coupled by brazing with a silver-copper braze. Electrical leads 203 may also be desirably coupled to electrical contacts 303 by brazing with a silver-copper braze. Further, the combination of top layer aperture 311 and bottom layer aperture 301 defines optical component mount 211.

[0040] Figure 4 shows an exemplary package in which optical component 400 (e.g. semiconductor laser) and optical fiber 410 have been installed. Optical component 400 is mounted on the base 200 through the optical component mount 211 and is further electrically coupled to the corresponding electrical contacts 303 with wirebonds 401. Additionally, optical component 400 may be coupled to the base 200 within the area defined by optical component mountable aperture 211 with submount preform 501 (not shown in figure 4), which may be formed from an indium alloy solder (e.g. InPb). Further, an optical fiber 410 is aligned such that it is optically coupled to optical component 400 and is then secured to fiber mountable pad 313 with fiber solder preform 411.

[0041] In an exemplary embodiment, wirebonds 401 may be formed from gold and optical fiber 410 may be desirably metallized with gold-nickel-gold so as to be compatible with a fiber solder preform 411 formed from gold-tin solder. In an alternate embodiment, optical fiber 410 may be non-metallized and fiber solder preform 411 may then be formed from glass solder. In such an alternate embodiment, there may not be the need for a fiber mountable pad 313 and optical fiber 410 may be secured directly to housing 210 with fiber solder preform 411 formed from glass solder.

[0042] Further, optical fiber 410 may be desirably optically coupled to optical component 400 by an alignment process which includes: 1) rough placement using optical vision cameras utilizing top and side camera views; 2) activation of the optical component, and 3) precise movement of the fiber in 3 axes so that the output signal from the optical component at the fiber output interface is a desired value. Typically, there is a 5-10 micron separation between optical fiber 410 and optical component 400.

[0043] Figure 5 shows an exploded perspective view of the basic package along with further components of an exemplary embodiment separately. An exemplary method of manufacturing a fiber-coupled optical component package may include coupling housing 210 to base 200, coupling electrical leads 203 to housing 210, coupling optical component 400 to housing 210 with submount preform 501, coupling optical fiber 410 to housing 210 with optical fiber preform 411, further coupling optical fiber 410 to housing 210 and package lid 540 at fiber opening 544 with fiber seal 503, and coupling package lid to housing 210 with lid seal preform 502. The method may also desirably include applying optical sealant 505 to fill gaps between optical fiber 410, housing 210, base 200, and package lid 540.

[0044] In an exemplary embodiment, package lid 540 may be formed from Kovar and fiber seal 503 and lid seal preform 502 may be formed from an indium alloy solder having a melting point lower than that of the submount preform 501 (e.g. InSn). In an alternate embodiment, fiber seal 503 and lid seal preform 502 may be formed from epoxy. Additionally, optical sealant 505 may be formed epoxy, silicone, or solder.

[0045] Figure 6 shows an assembled package with base 200, housing 210 mounted on base 200, leads 203 coupled to housing 210, fiber 410 coupled to housing 210, package lid 540 mounted on housing 210, and optical sealant 505 applied on fiber 410 at fiber opening 544 (not shown in figure 6) over a portion of base 200. Optical sealant 505 is desirably applied so that it fills gaps between fiber 410, base 200, housing 210, and lid 540.

[0046] Figure 7 is a flow chart showing several exemplary methods of manufacture of an exemplary embodiment of the present invention. The exemplary alternative methods

are illustrated using decision blocks in the flow chart. An actual assembly method would use one of the respective paths, without any decision blocks.

[0047] In step 701, top and bottom layer apertures are punched through an alumina green tape, whereupon which top and bottom layer substrates are punched from the green tape, each including a respective aperture. Next, in step 702, a fiber-coupled optical component housing including an optical component mountable aperture is formed by coupling the top and bottom layer substrates. It is understood that, in general, the housing may include any number of substrate layers. Electrical contact metallizations for receiving operational power may then be formed on the bottom layer substrate in step 703. In an alternate embodiment, step 703 is performed before step 702. In the exemplary embodiment of the invention, electrical contact metallizations are formed using a tungsten ink. After the contact metallizations are formed on the bottom layer substrate, the top layer substrate and bottom layer substrate may be laminated and fired using, for example, a high-temperature cofired ceramic (HTCC) process, to form the housing. At this point, the housing may be coupled to a high thermal conductivity base in step 703a, for example, by brazing, but this step may generally be postponed until as late as step 710.

[0048] At step 704, a decision is made whether the manufacturing process uses metallized optical fiber to be secured to the housing with metal solder, or a bare optical fiber to be secured to the housing with glass solder.

[0049] If a metallized fiber is to be used, in step 705a, one or more vias are formed on the housing, going through a top surface of the housing and connecting to the base. A metallic fiber mount pad is formed in step 706a, and one or more thin strips of metallization are formed connecting the mount pad to the one or more base-connecting vias in step 707a. Steps 706a and 707a are generally interchangeable. In step 708a, a decision is made whether the package lid is to be secured using solder. If so, then a metallic seal ring is formed on the surface of the housing in step 709a. If not, manufacturing proceeds to step 710, where all metallizations are electroplated.

[0050] If the decision is made to use a bare optical fiber with glass solder at step 704, then in step 705b a decision is made whether or not the package lid is to be secured using solder. If so, then it may be desired in step 706b to form one or more vias on the

housing, going through a top surface of the housing and connecting to the base. A metallic seal ring is then formed on the surface of the housing in step 707b. Manufacture then proceeds to step 710, where the seal ring metallization is electroplated. If the decision is made that the package lid is not to be secured using solder at step 705b, then manufacture proceeds to step 711.

[0051] At step 711, an optical component 400 (e.g. semiconductor laser) is mounted to the base 200 within the area defined by the housing aperture 311. In step 712, an optical fiber 410 is aligned to receive a desired output signal of the optical component and is then secured at that position using glass solder or metal solder, with a glass solder preform being applied directly over the fiber and onto the ceramic housing and a metal solder preform being applied directly over the metallized fiber and onto the metallic fiber mount pad 313. Once the preform is in place, it is heated to its melting temperature with one or more lasers (not shown) to melt the solder and secure the fiber.

[0052] A package lid 540 is then placed over one or more of the housing 210, the optical component 400, and a portion of fiber 410 in step 713. Also, the package lid may be secured using solder or an epoxy. In step 713a, an optional fiber seal 503 may be applied at an opening of the package lid 544 that allows passage of the fiber. This optional seal serves to secure the fiber at the fiber opening and may be, for example, solder or an epoxy. In step 714, an optional optical sealant may be applied at one or more of the package lid, the housing, the fiber, and the base to fill gaps and to further secure the fiber.

[0053] It can be seen that the exemplary embodiments of the present invention may be implemented using only vertical assembly processing steps. Further, as seen in figures 3A and 5, access to a side view of housing 210 mounted on base 200 may be provided. This allows monitoring manufacture with cameras, subsequently improving alignment accuracy associated with optically coupling fiber 410 to optical component 400. This may improve manufacturing yield as well as reduce process cycle times. The prior art presented in figures 1A and 1B do not support side view access to cameras. Additionally, optical component 400 and optical fiber 410 are mounted on shared housing 210, reducing the number of components needed and eliminating the prior art process step which places and attaches a separate fiber mount 5 to the package 1.

[0054] As described above, in alternate embodiments of the present invention, it may be desired to secure optical fiber 410 to housing 210 using glass solder and package lid 540 to housing 210 using epoxy, thereby eliminating the need for any metallization on top surface 310 of housing 210 as well as base-connecting vias 306.

[0055] Figure 8 shows another embodiment of the present invention. In this embodiment, an optical fiber 810 is optically coupled to laser output coupler 807 of laser 800. Fiber 810 is further mechanically coupled to the laser substrate 802 by solder preform 808 applied directly over fiber 810 on fiber mount pad 809. In an alternate embodiment, fiber 810 is soldered directly to laser substrate 802 without fiber mount pad 809. Laser 800 includes substrate 802 which may include a grating to provide lasing within an active layer 804 which may be, for example, a bulk gain material or a quantum well structure. Semiconductor layer 805 is formed over active layer 804 and is a material with an index of refraction that desirably isolates generated light to within the active layer. The front and rear facets of laser 800 may also be substantially reflective to provide lasing within the active layer. If a metallized optical fiber is used, a metallized fiber mount pad is formed over substantially planar fiber mount region 809 adjacent to substantially reflective laser output coupler 807 so that optical fiber 810 may be soldered to substantially planar fiber mount region 809 with solder 808, which may be metallic solder. Non-metallized optical fiber is soldered directly to laser substrate 802 over substantially planar fiber mount region 809 with solder 808, which may be glass solder. Electrode 806 is formed on top of the active layer to provide operational power. Laser 800 may also be coupled to high thermal conductivity base 801, over which a package lid (not shown in figure 8) may be secured. In an exemplary embodiment, substrate 802 may be formed from silicon carbide (SiC), indium phosphide (InP), or gallium arsenide (GaAs).

[0056] Figure 9 is a flow chart showing exemplary methods of manufacture of the exemplary embodiment shown in figure 8. The exemplary alternative methods are illustrated using decision blocks in the flow chart. An actual assembly method would use one of the respective paths, without any decision blocks.

[0057] In step 901, the substrate 802 is formed from a semiconductor material of a first conductivity type. The semiconductor material may be a p- or n-type III/V material. The active layer 804 is then formed on top of the substrate in step 903, and may be a

quantum well structure or a bulk gain material. In an alternate embodiment, optional step 902 may be performed to form a grating over a portion of the substrate in order to increase lasing within active layer 804 formed over the portion of the substrate in step 903. A semiconductor layer 805 of a second conductivity type is formed in step 904. The semiconductor layer may be a III/V material of a different type than the substrate with an index of refraction chosen to isolate radiation within the active layer. The substrate 802, active layer 804, and semiconductor layer 805 form a P-I-N laser diode structure. In step 905, an electrode layer 806 is formed from a high electrical conductivity material to provide operational power to the laser. Optional step 906 produces substantially reflective front and rear facets 803 of the device from one or more of a cleaved facet, a dielectric mirror, and a reflective surface coating. This is to further increase lasing feedback within the active layer. Although step 906 is shown to occur after step 905, it may generally be performed at any point after the active layer has been formed and before a package lid is in place. In step 907, a substantially transparent optical output coupler 807 is formed from one or more of a tilted surface, an antireflective surface coating, and a buried facet.

[0058] At step 908, a decision is made whether the manufacturing process uses metallized optical fiber to be secured to the substrate with metal solder, or a bare optical fiber to be secured to the substrate with glass solder.

[0059] If a metallized fiber is to be used, in step 909a, a metallic fiber mount pad is formed over the substantially planar fiber mount region 809. Then in step 910a, the metallized fiber 810 is aligned to receive a desirable output signal of the optical output coupler and is soldered in place over the fiber mount pad with a metal solder preform 808.

[0060] If a bare fiber is to be used, in step 909b, a glass solder adapted fiber mount pad is formed over the substantially planar fiber mount region 809. Then in step 910b, the bare fiber 810 is aligned to receive a desirable output signal of the optical output coupler and is soldered in place over the fiber mount pad with a glass solder preform 808.

[0061] Once the respective solder preform is in place, it is heated to its melting temperature with one or more lasers (not shown) to melt the solder and secure the fiber.

[0062] At this point, the optical component may be coupled to a high thermal conductivity base 801 in optional step 911, for example, by soldering, but this step may generally be performed as early as step 902.

[0063] A package lid may then be placed over the optical component in optional step 912. The package lid may be secured using solder or an epoxy.

[0064] Figures 10A, 10B, 11A, and 11B show additional embodiments of the present invention, wherein an optical component (e.g. semiconductor laser chip) is coupled directly to the package housing, avoiding the use of an optical component package submount (e.g. 400 in Fig. 5). In both embodiments of Figures 10A, 10B, 11A, and 11B, an optical component is mounted directly on a high thermal conductivity base.

[0065] Figure 10A shows a perspective view of one such embodiment where optical component 1840 is mounted directly to high thermal conductivity base 1801. High thermal conductivity base 1801 features a mesa portion that extends through an aperture of low thermal conductivity substrate 1802 (more clearly seen in the cross-sectional side view of Fig. 10B taken along the cut line 11B-11B, shown in Fig. 10A). Low thermal conductivity substrate 1802 may be coupled to the high thermal conductivity base 1801 by brazing, for example, with a silver-copper braze, or by soldering, for example, with a gold-germanium or gold-silicon solder. Further, the top surface of the optical component may be metallized desirably to serve as an electrical contact for providing operational power or ground. Additional metallization (not shown in Fig. 10) may be formed on low thermal conductivity base 1802 to serve as an electrical contact for providing ground or operational power, respectively. Further metallization (not shown in Fig. 10) may be formed on low thermal conductivity substrate 1802 for mounting a lid (not shown in Fig. 10) over the package, and for mounting a metallized optical fiber 1810 over fiber mount region 1815 with metal solder 1811.

[0066] Figure 11A shows a perspective view of another such embodiment where optical component 1940 is mounted directly to high thermal conductivity base 1901. High thermal conductivity base 1901 features a low thermal conductivity substrate 1902 (more clearly seen in the cross-sectional side view of Fig. 11B taken along the cut line 11B-11B, shown in Fig. 11A) abutting with a top surface at the same level as the base. Low thermal

conductivity substrate 1902 may be coupled to high thermal conductivity base 1901 by brazing, for example, with a silver-copper braze, or soldering, for example, with a gold-germanium or gold-silicon solder. Further, the top surface of the optical component may be metallized to desirably serve as an electrical contact for providing operational power or ground. Additional metallization (not shown in Fig. 11) may be formed on low thermal conductivity base 1902 over fiber mount region 1915 for mounting a metallized optical fiber 1910 with metal solder 1911.

[0067] Typically, submounts are used for laser chip mounting because of yield issues during their initial burn-in. If the laser chip fails burn-in, the submount and laser are discarded, making the cost of the submount a significant contributor to final production costs. Submounts are used, however, since component packages according to the prior art are typically too expensive to allow burn-in of the laser chip directly without the submount. The exemplary embodiments of the present invention may be manufactured much less expensively than the prior art packages, but still not as cheaply as a submount. However, the differential cost between the submount and an exemplary embodiment of the present invention may be offset by the reduction in manufacturing material and assembly steps gained by mounting an optical component directly on the final package assembly during the initial assembly steps.

[0068] Although illustrated and described above with reference to certain specific embodiments, the present invention is nevertheless not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.